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Standard Test Methods for Deep ~~Foundations~~ Foundation Elements Under Static Axial Tensile Load[1]

This standard is issued under the fixed designation D3689/D3689M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

~~ε[1] NOTE—Designation was editorially corrected to match units information in June 2013.~~

1. Scope

1.1 The test methods described in this standard measure the axial deflection of ~~a~~ an individual vertical or inclined deep foundation element or group of elements when loaded in static axial tension. These methods apply to all ~~deep foundations,~~ types of deep foundations, or deep foundation systems, as they are practical to test. The individual components of which are referred to herein as ~~"piles,"~~ elements that function as, or in a manner similar ~~to driven piles or cast in place piles,~~ to, drilled shafts; cast-in-place piles (augered cast-in-place piles, barrettes, and slurry walls); driven piles, such as pre-cast concrete piles, timber piles or steel sections (steel pipes or wide flange beams); or any number of other element types, regardless of their method of ~~installation, and~~ installation. Although the test methods may be used for testing single ~~piles or pile groups. The~~ elements or element groups, the test results may not represent the long-term performance of ~~a deep foundation.~~ the entire deep foundation system. A summary of the test methods is contained in Section 4.

1.2 This standard provides minimum requirements for testing deep ~~foundations~~ foundation elements under static axial tensile load. ~~Plans,~~ Project plans, specifications, provisions, or any combination thereof ~~prepared by a qualified engineer~~ may provide additional requirements and procedures as needed to satisfy the objectives of a particular test program. The engineer in ~~responsible~~ charge of the foundation design, referred to herein as the foundation engineer, shall approve any deviations, deletions, or additions to the requirements of this standard. (Exception: the test load applies to the testing apparatus shall not exceed the rated capacity established by the engineer who designed the testing apparatus.)

~~1.3 This standard allows the following test procedures:~~

~~Procedure~~	~~Test~~	~~Section~~
~~A~~	~~Quick Test~~	~~8.1.2~~
~~B~~	~~Maintained Test (optional)~~	~~8.1.3~~
~~C~~	~~Loading in Excess of Maintained Test (optional)~~	~~8.1.4~~
~~D~~	~~Constant Time Interval Test (optional)~~	~~8.1.5~~
~~E~~	~~Constant Rate of Uplift Test (optional)~~	~~8.1.6~~
~~F~~	~~Cyclic Loading Test (optional)~~	~~8.1.7~~

1.3 Apparatus and procedures herein designated "optional" may produce different test results and may be used only when approved by the foundation engineer. The word "shall" indicates a mandatory provision, and the word "should" indicates a recommended or advisory provision. Imperative sentences indicate mandatory provisions.

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.11 on Deep Foundations.

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1.4 ~~A qualified geotechnical~~ The foundation engineer should interpret the test results obtained from the procedures of this standard ~~so as~~ to predict the actual performance and adequacy of ~~piles~~elements used in the constructed foundation. ~~See Appendix X1 for comments regarding some of the factors influencing the interpretation of test results.~~

1.5 ~~A qualified engineer~~ An engineer qualified to perform such work shall design and approve all loading apparatus, loaded members, ~~support frames, and~~ and support frames. The foundation engineer shall design or specify the test procedures. The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered requirements of the standard. This standard also includes illustrations and appendices intended only for explanatory or advisory use.

1.6 *Units—*The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system ~~are~~may not ~~necessarily~~be exact equivalents; therefore, ~~to ensure conformance with the standard,~~ each system shall be used independently of the ~~other, and~~other. Combining values from the two systems ~~shall not be combined.~~may result in non-conformance with the standard.

1.7 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound [lbf] represents a unit of force [weight], while the unit for mass is ~~slugs.~~slug. The rationalized slug unit is not given, unless dynamic [F=ma] calculations are involved.

1.8 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026. The procedure used to specify how data are collected, recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering data.

1.9 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.10 ~~*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users*~~ *This standard offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this standard* ~~*are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*~~*may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

1.11 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate* ~~*safety*~~ *safety, health, and* ~~*health*~~*environmental practices and determine the applicability of regulatory limitations prior to use.*

1.12 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D5882 Test Method for Low Strain Impact Integrity Testing of Deep Foundations
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D6760 Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing
D7949 Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations
D8169/D8169M Test Methods for Deep Foundations Under Bi-Directional Static Axial Compressive Load

2.2 ~~*American National*~~ *ASME Standards:*[3]
ASME B30.1 Jacks
ASME B40.100 Pressure Gages and Gauge Attachments
ASME B89.1.10.M Dial Indicators (For Linear Measurements)

3. Terminology

3.1 *Definitions*—For ~~common~~ definitions of common technical terms used in this ~~standard see~~ standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cast in-place pile, n*—a deep foundation ~~unit~~element made of cement grout or concrete and constructed in its final location, ~~e.g.~~ for example, drilled shafts, bored piles, caissons, ~~auger cast~~augered cast-in-place piles, pressure-injected footings, etc.

3.2.2 *deep ~~foundation,~~ foundation element, n*—a relatively slender structural element that transmits some or all of the load it supports to soil or rock well below the ground surface, such as a steel pipe ~~pile~~ or ~~concrete~~concrete-filled drilled shaft.

3.2.3 *driven pile, n*—a deep foundation ~~unit~~element made of preformed material with a predetermined shape and size and typically installed by impact hammering, vibrating, or ~~pushing.~~jacking.

3.2.4 *failure load, n*—~~for the purpose of terminating an axial tensile load test,~~the ~~the~~ test load at which continuing, progressive movement occurs, or at which the total axial movement exceeds ~~15 % of the pile diameter or width, or as~~ the value specified by the ~~engineer.~~ foundation engineer.

3.2.5 *gage or gauge, n*—an instrument used for measuring load, pressure, displacement, strain or such other physical properties associated with load testing as may be required.

3.2.6 *reaction, n*—a device or deep foundation element or elements designed to provide resistance in the opposite direction of the test load.

3.2.7 *telltale rod, n*—an unstrained metal rod extended through the test ~~pile~~element from a specific point to be used as a reference from which to measure the change in the length of the loaded ~~pile.~~element.

3.2.8 *toe, n*—the bottom of a deep foundation element, sometimes referred to as tip or base.

3.2.9 *wireline, n*—a steel wire mounted with a constant tension force between two supports and used as a reference line to read a scale indicating movement of the test ~~pile.~~element.

4. Summary of Test Method

4.1 This standard provides minimum requirements for testing deep foundation elements under static axial tensile load. The test is a specific type of test, most commonly referred to as deep foundation load testing or static load testing. This standard is confined to test methods for loading a deep foundation element or elements from the top, in the upward direction. The loading requires devices or structural elements be constructed that resist downward movement, often referred to collectively as a reaction system. The principal measurements taken in addition to load are displacements.

4.2 This standard allows the following test procedures:

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[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, ~~Three~~Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

Method A	Quick Test	10.1.2
Method B	Maintained Test	10.1.3
Method C	Constant Rate of Uplift Test	10.1.4

5. Significance and Use

5.1 Field tests provide the most reliable relationship between the axial load applied to a deep foundation and the resulting axial movement. Test results may also provide information used to assess the distribution of side shear resistance along the ~~pile shaft~~ element and the long-term load-deflection behavior. ~~A~~The foundation ~~designer~~engineer may evaluate the test results to determine if, after applying ~~an~~ appropriate ~~factor~~factors of safety, the ~~pile~~element or ~~pile~~ group ~~has an ultimate static capacity and a~~ of elements has a static capacity, load response and deflection at service load satisfactory to support ~~a specific~~ the foundation. When performed as part of a ~~multiple-pile~~multiple-element test program, the ~~designer~~ foundation engineer may also use the results to assess the viability of different ~~piling types~~ sizes and types of foundation elements and the variability of the test site.

5.2 If ~~feasible,~~ feasible and without exceeding the safe structural load on the ~~pile(s) or pile cap,~~ element or element cap (hereinafter unless otherwise indicated, "element" and "element group" are interchangeable as appropriate), the maximum load applied should reach a failure load from which the foundation engineer may determine the ~~ultimate~~ axial static tensile load capacity of the ~~pile(s).~~element. Tests that achieve a failure load may help the ~~designer~~ foundation engineer improve the efficiency of the foundation design by reducing the ~~piling~~ foundation element length, quantity, ~~or~~and/or size.

5.3 If deemed impractical to apply axial test loads to an inclined ~~pile,~~element, the foundation engineer may elect to use axial test results from a nearby vertical ~~pile~~element to evaluate the axial capacity of the inclined ~~pile.~~ element. The foundation engineer may also elect to use a bi-directional axial test on an inclined element (D8169/D8169M).

5.4 Different loading test procedures may result in different load-displacement curves. The Quick Test (10.1.2) and Constant Rate of Uplift Test (10.1.4) typically can be completed in a few hours. Both are simple in concept, loading the element relatively quickly as load is increased. The Maintained Test (10.1.3) loads the element in larger increments and for longer intervals, which could cause the test duration to be significantly longer. Because of the larger load increments the determination of the failure load can be less precise, but the Maintained Test is thought to give more information on creep displacement. Although control of the Constant Rate of Uplift Test is somewhat more complicated (and uncommon for large diameter or capacity elements), the test may produce the best possible definition of capacity. The foundation engineer must weigh the complexity of the procedure and other limitations against any perceived benefit.

5.5 The scope of this standard does not include analysis for foundation capacity in tension, but in order to analyze the test data appropriately it is important that information on factors that affect the derived mobilized static axial tensile capacity are properly documented. These factors may include, but are not limited to, the following:

5.5.1 Potential residual loads in the element which could influence the interpreted distribution of load along the element shaft.

5.5.2 Possible interaction of friction loads from test element with downward friction transferred to the soil from reaction elements obtaining part or all of their support in soil at levels above the tip level of the test element.

5.5.3 Changes in pore water pressure in the soil caused by element driving, construction fill, and other construction operations which may influence the test results for frictional support in relatively impervious soils such as clay and silt.

5.5.4 Differences between conditions at time of testing and after final construction such as changes in grade or groundwater level.

5.5.5 Potential loss of soil supporting the test element from such activities as excavation and scour.

5.5.6 Possible differences in the performance of an element in a group or of an element group from that of a single isolated element.

5.5.7 Effect on long-term element performance of factors such as creep, environmental effects on element material, negative friction loads not previously accounted for, and strength losses.

5.5.8 Type of structure to be supported, including sensitivity of structure to settlements and relation between live and dead loads.

5.5.9 Special testing procedures which may be required for the application of certain acceptance criteria or methods of interpretation.

5.5.10 Requirement that non-tested element(s) have essentially identical conditions to those for tested element(s) including, but not limited to, subsurface conditions, element type, length, size and stiffness, and element installation methods and equipment, so that application or extrapolation of the test results to such other elements is valid. For concrete elements, it is sometimes necessary to use higher amounts of reinforcement in the test elements in order to safely conduct the test to the predetermined required test load. In such cases, the foundation engineer shall account for the difference in stiffness between the test elements and non-tested elements.

5.5.11 Tension tests are sometimes used to validate element compression capacity in addition to tension capacity. When subjected to tension loads, elements may have different stiffness and structural capacity compared to elements subjected to compression loads.

NOTE 1—The quality of the result produced by these test methods is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of these test methods are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Test Foundation Preparation

6.1 Excavate or add fill to the ground surface around the test ~~pile or pile group~~ element to the final design elevation unless otherwise approved by the ~~engineer.~~foundation engineer. Type of fill and compaction requirements shall be as specified by the foundation engineer.

6.2 Design and construct the test ~~pile(s)~~element so that any location along the depth of the ~~pile~~element will safely sustain the maximum anticipated ~~axial compressive and tensile load~~ loads to be developed at that location. Cut off or build up the test ~~pile(s)~~element as necessary to permit construction of the load-application apparatus, placement of the necessary testing and instrumentation equipment, and observation of the instrumentation. Remove any damaged or unsound material from the ~~pile~~element top as necessary to properly install the apparatus for measuring movement, for applying load, and for measuring load.

6.3 For tests on ~~pile~~element groups, cap the ~~pile~~element group with steel-reinforced concrete or a steel load frame designed ~~to safely sustain the anticipated loads.~~for the anticipated loads by the structural engineer.

6.4 Install structural tension connectors extending from the test ~~pile~~element or ~~pile~~element cap, constructed of steel straps, bars, cables, and/or other devices bolted, welded, cast into, or otherwise firmly affixed to the test ~~pile~~element or ~~pile~~element cap to safely apply the maximum required ~~tensile~~ test load without slippage, rupture, or excessive elongation. Carefully inspect these tension members for any damage that may reduce their tensile capacity. Tension members with a cross-sectional area reduced by corrosion or damage, or material properties compromised by fatigue, bending, or excessive heat, may rupture suddenly under load. Do not use brittle materials for tension connections.

NOTE 2—Deep foundations sometimes include hidden defects that may go unnoticed prior to static testing. Low strain integrity tests as described in Test Method D5882 ~~and~~ , ultrasonic crosshole integrity tests as described in Test Method D6760, and thermal integrity profiling as described in Test Methods D7949 may provide a useful pre-test evaluation of the test foundation. While the former two methods can be done at any time, including after the load test, thermal integrity profiling must be done relatively soon after the concrete element is cast.

NOTE 3—When testing a cast-in-place concrete element such as a drilled shaft, the size, shape, material composition and properties of the element can influence the element capacity and the interpretation of strain measurements described in Section 8.

7. Safety Requirements

7.1 All operations in connection with element load testing shall be carried out in such a manner to minimize, avoid, or eliminate the exposure of people to hazard. The following safety rules are in addition to general safety requirements applicable to construction operations:

7.1.1 Keep all test and adjacent work areas, walkways, platforms, etc. clear of scrap, debris, small tools, and accumulations of snow, ice, mud, grease, oil, or other slippery substances.

7.1.2 Provide timbers, blocking and cribbing materials made of quality material and in good serviceable condition with flat surfaces and without rounded edges.

7.1.3 Hydraulic jacks shall be equipped with hemispherical bearings or shall be in complete and firm contact with the bearing surfaces and shall be aligned with axis of loading to avoid eccentric loading.

7.1.4 Loads shall not be hoisted, swung, or suspended over any person and shall be controlled by tag lines.

7.1.5 For tests on inclined elements, all inclined jacks, bearing plates, test beam(s), or frame members shall be firmly fixed into place or adequately blocked to prevent slippage upon release of load.

7.1.6 All test beams, reaction frames, platforms, and boxes shall be adequately supported at all times.

7.1.7 Only authorized personnel shall be permitted within the immediate test area, and only as necessary to monitor test equipment. The overall load test plan should include all provisions and systems necessary to minimize or eliminate the need for personnel within the immediate test area. All reasonable effort shall be made to locate pumps, load cell readouts, data loggers, and test monitoring equipment at a safe distance away from jacks, loaded beams, weighted boxes, dead weights, and their supports and connections.

7.1.8 The requirements in this section have been developed to assist in the preparations for the testing process, but should not be considered completely comprehensive of all safety issues. Safety matters should be carefully considered with the list above being a starting point for any safety planning.

8. Apparatus for Applying and Measuring Loads

8.1 *General:*

8.1.1 The apparatus for applying tensile loads to a test ~~pile or pile group~~ element shall conform to one of the methods described in ~~6.3~~8.3 – ~~6.6~~8.6. The apparatus for applying and measuring loads described in this section shall be designed in accordance with recognized standards by a qualified engineer who shall clearly define the maximum allowable load that can be safely applied. The method in ~~6.3~~8.3 is recommended. The method in ~~6.5~~8.5 can develop high tensile loads with relatively low jacking capacity, but does not perform well for tests to failure or for large upward movements. All described methods require careful setup to ensure a safe test environment.

8.1.2 Reaction ~~piles,~~elements, if used, shall be of sufficient number and installed ~~so as~~ to safely provide adequate reaction capacity without excessive movement. When using two or more reaction ~~piles~~elements at each end of the test beam(s), cap them with reaction beams (Fig. 1). Locate reaction ~~piles~~elements so that resultant test beam load supported by them acts at the center of the reaction ~~pile~~element group. Cribbing, if used as a reaction, shall be of sufficient plan dimensions to transfer the reaction loads to the soil without settling at a rate that would prevent maintaining the applied loads.

8.1.3 Cut off or build up reaction ~~piles~~elements as necessary to place the reaction or test beam(s). Remove any damaged or unsound material from the top of the reaction ~~piles,~~elements, and provide a smooth bearing surface parallel to the reaction or test beam(s). To minimize stress concentrations due to minor surface irregularities, set steel bearing plates on the top of precast or cast-in-place concrete reaction ~~piles~~elements in a thin layer of quick-setting, non-shrink grout, less than 6 mm [0.25 in.] thick and having a compressive strength greater than the reaction ~~pile~~element at the time of the test. For steel reaction ~~piles,~~elements, weld a bearing plate to each ~~pile,~~element, or weld the cap or test beam(s) directly to each ~~pile.~~element. For timber reaction ~~piles,~~elements, set the bearing plate(s) directly on the cleanly cut top of the ~~pile,~~element, or in grout as described for concrete ~~piles.~~elements.

8.1.4 Provide a clear distance between the test ~~pile(s)~~element(s) and the reaction ~~piles~~elements or cribbing of at least five times the maximum diameter of the largest test or reaction ~~pile(s),~~element(s), but not less than 2.5 m [8 ft]. The engineer may increase or decrease this minimum clear distance based on factors such as the type and depth of reaction, soil conditions, and magnitude of loads so that reaction forces do not significantly ~~effect~~affect the test results.

NOTE 4—Excessive vibrations during reaction ~~pile~~element installation in non-cohesive soils may affect test results. Reaction ~~piles~~elements that penetrate deeper than the test ~~pile~~element may affect test results. ~~Install the anchor piles nearest the test pile~~ Reaction elements nearest to the test element should be installed first to help reduce installation effects. A clear distance of five (5) times the maximum element diameter may be impractical for larger elements.

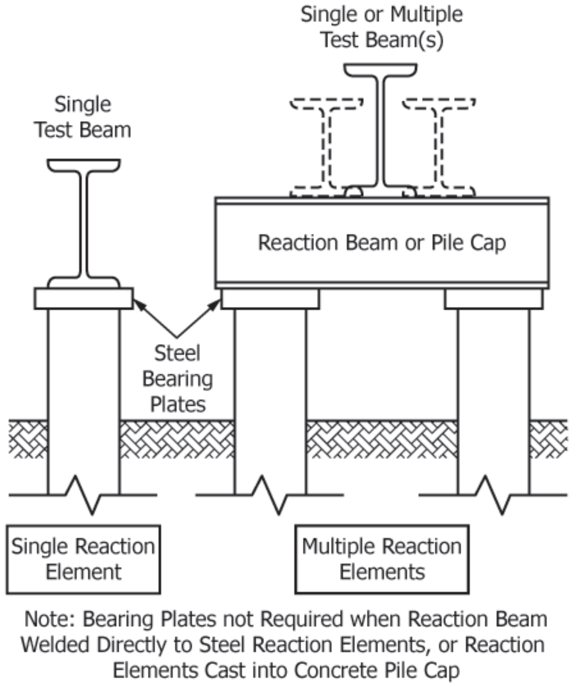

FIG. 1 Typical End Views of Test Beam(s) and Reaction Pile(s)

8.1.5 Each jack shall include a lubricated hemispherical bearing or similar device to minimize lateral loading of the ~~pile or pile group.~~ test element. The hemispherical bearing(s) should include a locking mechanism for safe handling and setup.

8.1.6 Provide bearing stiffeners as needed between the flanges of test and reaction beams.

8.1.7 Provide steel bearing plates to spread the load to and between the jack(s), load cell(s), hemispherical bearing(s), test beam(s), reaction beam(s), and reaction ~~pile(s).~~element(s). Unless otherwise specified by the engineer, the size of the bearing plates shall be not less than the outer perimeter of the jack(s), load cell(s), or hemispherical bearing(s), nor less than the total width of the test beam(s), reaction beam(s), reaction ~~piles so as~~ elements to provide full bearing and distribution of the load. Bearing plates supporting the jack(s), test beam(s), or reaction beams on timber or concrete cribbing shall have an area adequate for safe bearing on the cribbing.

8.1.8 Unless otherwise specified, where using steel bearing plates, provide a total plate thickness adequate to spread the bearing load between the outer perimeters of loaded surfaces at a maximum angle of 45 degrees to the loaded axis. For center hole jacks and center hole load cells, also provide steel plates adequate to spread the load from their inner diameter to the ~~their~~ central axis at a maximum angle of 45 degrees, or per manufacturer recommendations.

8.1.9 Align the test load apparatus with the longitudinal axis of the test ~~pile or pile group~~ element to minimize eccentric loading. Align bearing plate(s), jack(s), load cell(s), and hemispherical bearing(s) on the same longitudinal axis. Place jacks to center the load on the test beam(s). Place test beam(s) to center the load on reaction beams or cribbing, and reaction beams to center the load on reaction piles or cribbing. These plates, beams, and devices shall have flat, parallel bearing surfaces. Set bearing plates on cribbing in the horizontal plane.

8.1.10 When testing inclined ~~piles,~~elements, align the test apparatus and reaction ~~piles~~elements parallel to the inclined longitudinal axis of the test ~~pile(s)~~element(s) and orient the test beam(s) perpendicular to the direction of incline.

8.1.11 ~~A qualified engineer~~ Qualified engineers shall design and approve all aspects of the loading apparatus, including loaded members, support frames, ~~and loading procedures. Unless otherwise specified by the engineer, the~~ tension connections (material, diameter, weld or embedment length, etc.), reaction elements, instruments and loading procedures. The apparatus for applying and measuring ~~loads,~~ loads (except for hydraulic jacks and load cells), including all structural members, shall have sufficient size, strength, and stiffness to safely prevent excessive deflection and instability up to ~~120 % of~~ the maximum anticipated test load.

NOTE 5—Rotations and lateral displacements of the test ~~pile or test pile group, reaction piles,~~element, reaction elements, cribbing support(s), or ~~pile cap(s)~~element cap may occur during loading, especially for ~~sites with weak soils. The user should design and construct the support reactions to prevent instability and to limit undesired~~elements extending above the soil surface or through weak soils. Support reactions, loading apparatus and equipment should be designed and constructed to resist any undesirable or possibly dangerous rotations or lateral displacements. These displacements should be monitored during the test so the test can be immediately halted if undesirable rotations or lateral displacements occur.

8.2 *Hydraulic Jacks, Gages, Transducers, and Load Cells:*

8.2.1 The hydraulic jack(s) and their operation shall conform to ASME ~~B30.1 and~~ B30.1. Jack(s) and load cell(s) shall have a nominal load capacity exceeding the maximum anticipated ~~jack~~test load by at least 20 %. The jack, pump, and any hoses, pipes, fittings, gages, or transducers used to pressurize it shall be rated to a safe pressure corresponding to the nominal jack capacity.

8.2.2 The hydraulic ~~jack ram(s)~~ jack(s) shall have a ram (piston, rod) travel greater than the sum of the anticipated maximum axial movement of the ~~pile~~element plus the deflection of the ~~test beam~~reaction system and the elongation of the tension connection, but not less than 15 % of the average ~~pile diameter or width.~~ element diameter or width (or any other specified and approved displacement requirement). Use a single high capacity jack when possible. When using a multiple jack system, provide jacks of the same make, model, and capacity, and supply the jack pressure through a common manifold with a master pressure ~~gage.~~ gage, and operated by a single hydraulic pump. Fit the manifold and each jack with a pressure gage to detect malfunctions and imbalances.

8.2.3 Unless otherwise specified, the hydraulic jack(s), pressure gage(s), and pressure transducer(s) shall ~~have a calibration~~each be calibrated to at least the maximum anticipated jack load performed within the six months prior to each test or series of tests. Furnish the calibration report(s) prior to performing a ~~test, which~~ test. Each report shall include the ambient temperature and individual calibrations shall be performed for multiple discrete ram strokes up to the maximum stroke of the jack.

8.2.4 Each complete jacking and pressure measurement system, including the hydraulic pump, should be calibrated as a unit when practicable. The hydraulic jack(s) shall be calibrated over the complete range of ram travel for increasing and decreasing applied loads. ~~If two or more jacks are to be used to apply the test load, they shall be of the same make, model, and size, connected to a common manifold and pressure gage, and operated by a single hydraulic pump.~~ The calibrated jacking system(s) shall have accuracy within 5 % of the maximum applied load. When not feasible to calibrate a jacking system as a unit, calibrate the jack, pressure gages, and pressure transducers separately, and each of these components shall have accuracy within 2 % of the applied load.

8.2.5 Pressure gages ~~shall have minimum graduations less than or equal to 1 % of the maximum applied load and shall conform to ASME B40.100 with an accuracy grade 1A having a permissible error ±1 % of the span. Pressure~~ and pressure transducers shall have ~~a minimum~~ ~~resolution~~resolutions less than or equal to 1 % of the maximum applied load and shall conform to ASME B40.100 with an accuracy grade 1A having a permissible error ±1 % of the span. When used for control of the test, pressure transducers shall include a real-time display.

8.2.6 ~~If the maximum test load will exceed 900 kN [100 tons], place a properly constructed~~Place a properly positioned load cell or equivalent device in series with each hydraulic jack. Unless otherwise specified the load ~~cell(s)~~cell shall have a calibration to at least the maximum anticipated jack load performed within the six months prior to each test or series of tests. The calibrated load ~~cell(s) or equivalent device(s)~~ cell shall have accuracy within 1 % of the applied load, including an eccentric loading of up to 1 % applied at an eccentric distance of 25 mm [1 in.]. After calibration, load cells shall not be subjected to impact loads. ~~A load cell is recommended, but not required, for lesser load. If not practicable to use a load cell when required, include embedded strain gages located in close proximity to the jack to confirm the applied load.~~

8.2.7 Do not leave the hydraulic jack pump unattended at any time during the test. ~~An automatic regulator is recommended to help hold the load constant as pile movement occurs.~~ Automated jacking systems shall include a clearly marked mechanical override to safely reduce hydraulic pressure in an emergency.

8.3 ~~*Tensile*~~ *Load Applied by Hydraulic Jack(s) Supported on Test Beam(s)* (Figs. 2 and 3~~) —~~)—Support the ends of the test beam(s) on reaction ~~piles~~elements or cribbing, using reaction beams as needed to cap multiple reaction ~~piles~~elements as shown in Fig. 1. Place the hydraulic jack(s), load cell(s), hemispherical bearing(s), and bearing plates on top of the test beam(s). Center a reaction frame over the jack(s), and anchor it to the tension connections (see ~~5.4~~6.4) extending from the test ~~pile or pile group.~~ element. Design and construct the test beam(s), reaction frame, and reaction ~~piles~~elements or cribbing, and arrange the jack(s) symmetrically ~~so as~~ to apply the resultant tensile load at, and parallel to, to the longitudinal axis of the test ~~pile or pile group.~~ element. Leave adequate clear space beneath the bottom flange(s) of the test beam(s) to allow for the maximum anticipated upward movement of the test ~~pile or pile cap~~ element plus the deflection of the test beam(s).

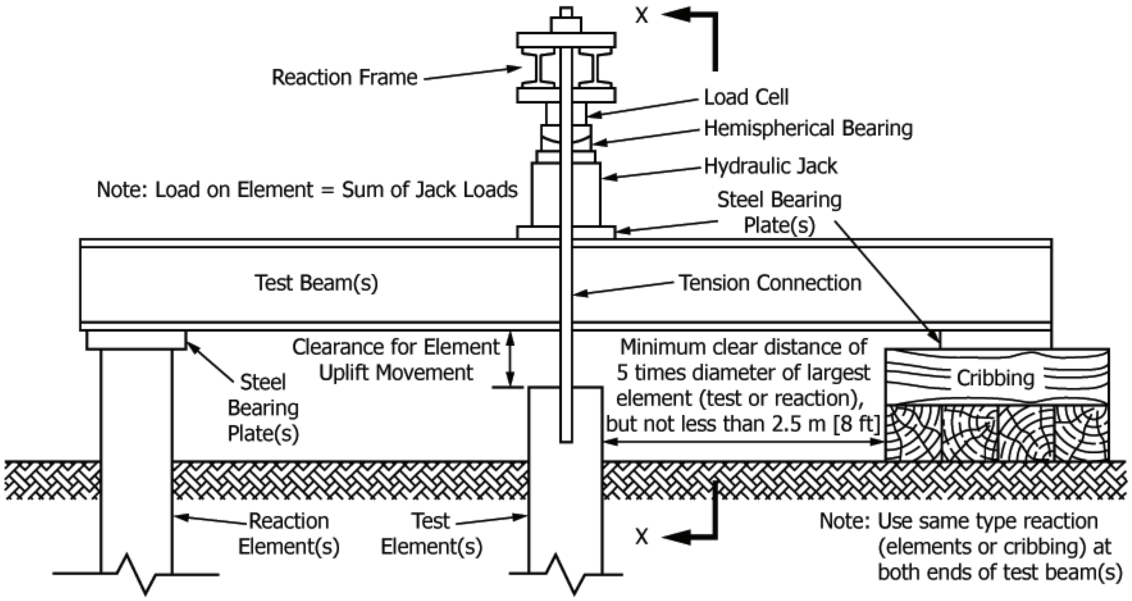

FIG. 2 Typical Setup for ~~Tensile~~ Load Test Using Hydraulic Jack(s) Supported on Test ~~Beams~~Beam(s)

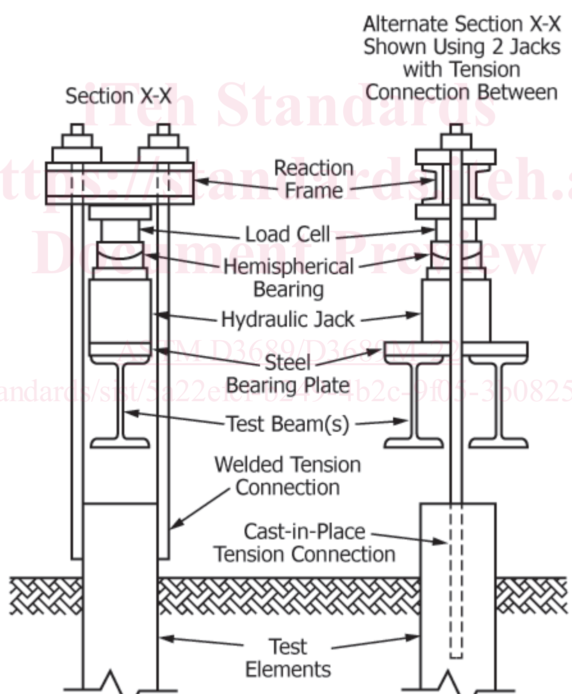

FIG. 3 Typical Section X-X (Fig. 2) of Test Beam(s) at Test ~~Pile~~Element(s)

8.4 *~~Tensile~~ Load Applied by Hydraulic Jacks Acting Upward at Both Ends of Test Beam(s) (*Figs. 4 and 5*)*—Support each end of the test beam(s) on hydraulic jack(s) centered beneath the beam web(s) and placed equidistant from the longitudinal axis of the test ~~pile or pile group.~~ element. Support the jacks on reaction ~~piles~~elements or cribbing, using reaction beams as needed to cap multiple reaction ~~piles.~~elements. Center a reaction frame over the test beam(s) and anchor it to the tension connections (see ~~5.4~~6.4) extending from the test ~~pile or pile group.~~ element. Place a single load cell and hemispherical bearing between the reaction frame and the test beam(s) (preferred), or alternatively, place a load cell and hemispherical bearing with each jack beneath the test beam(s). Design and construct the test beam(s), reaction frame, and reaction ~~piles~~elements or cribbing, and arrange the jack(s) symmetrically ~~so as~~ to apply the resultant tensile load at, and parallel to, ~~to~~ the longitudinal axis of the test ~~pile or pile group.~~element.

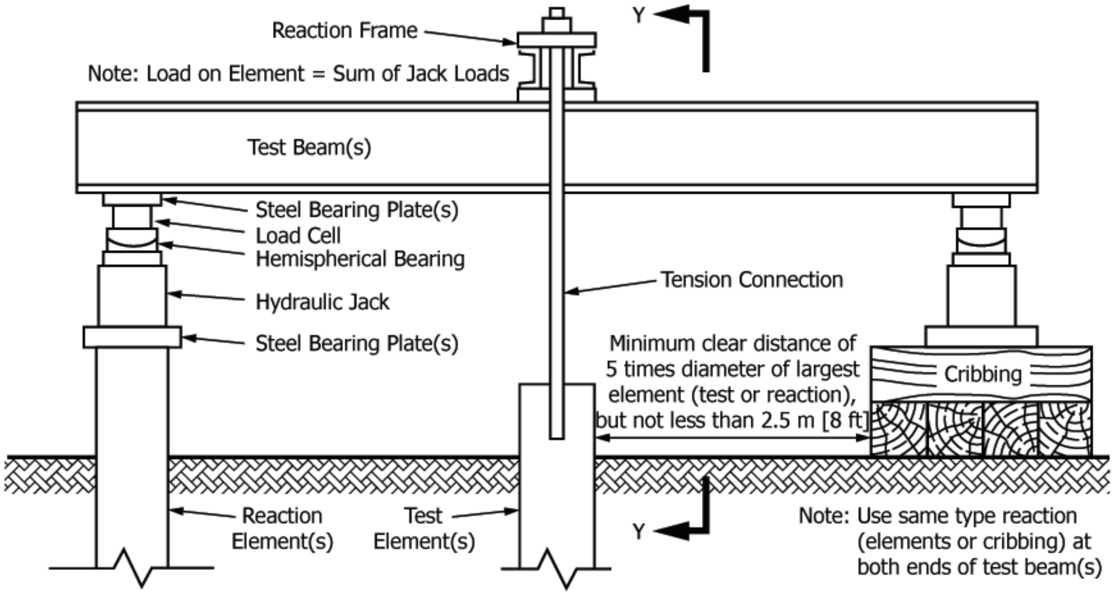

FIG. 4 Typical Setup for Tensile Load Test Using Hydraulic Jacks Acting Upward on Both Ends of Test Beam(s)

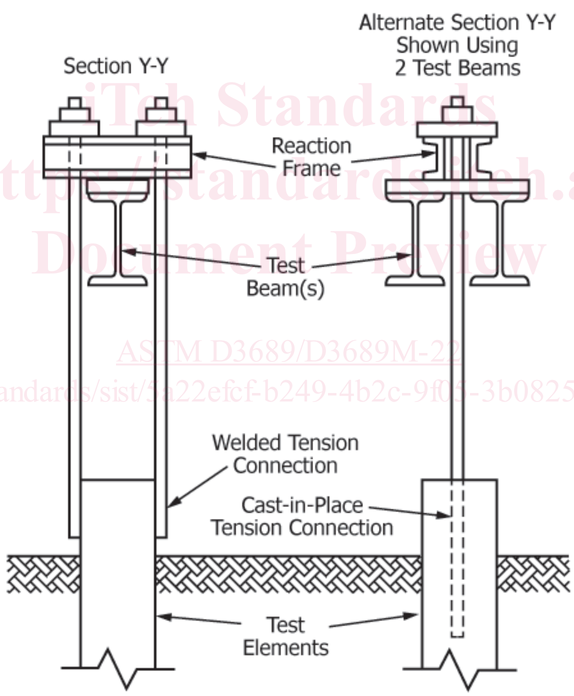

FIG. 5 Typical Section Y-Y (Fig. 4, Fig. 6) of Test Beam(s) at Test PileElement(s)

8.5 *Tensile Load Applied by Hydraulic Jack(s) Acting Upward at One End of Test Beam(s) (Figs. 5 and 6)*—Support one end of the test beam(s) on hydraulic jack(s) centered beneath the beam web(s). Support the jacks on reaction piles or cribbing, using reaction beams as needed to cap multiple reaction piles.elements. Support the other end of the test beam(s) on a steel fulcrum or similar device placed on a steel plate supported on a reaction pile(s)element(s) or cribbing, using reaction beams as needed to cap multiple reaction piles.elements. Center a reaction frame over the test beam(s) and anchor it to the tension connections (see 5.46.4) extending from the test pile or pile group. element. Place a single load cell and hemispherical bearing between the reaction frame and the test beam(s) (preferred), or alternatively, place a load cell and hemispherical bearing with each jack beneath the test beam(s). If using the latter arrangement, obtain accurate measurements of the plan locations of the jack(s), test pile or pile group, element, and the fulcrum to determine the magnification factor to apply to the measured loads to determine the resultant tensile

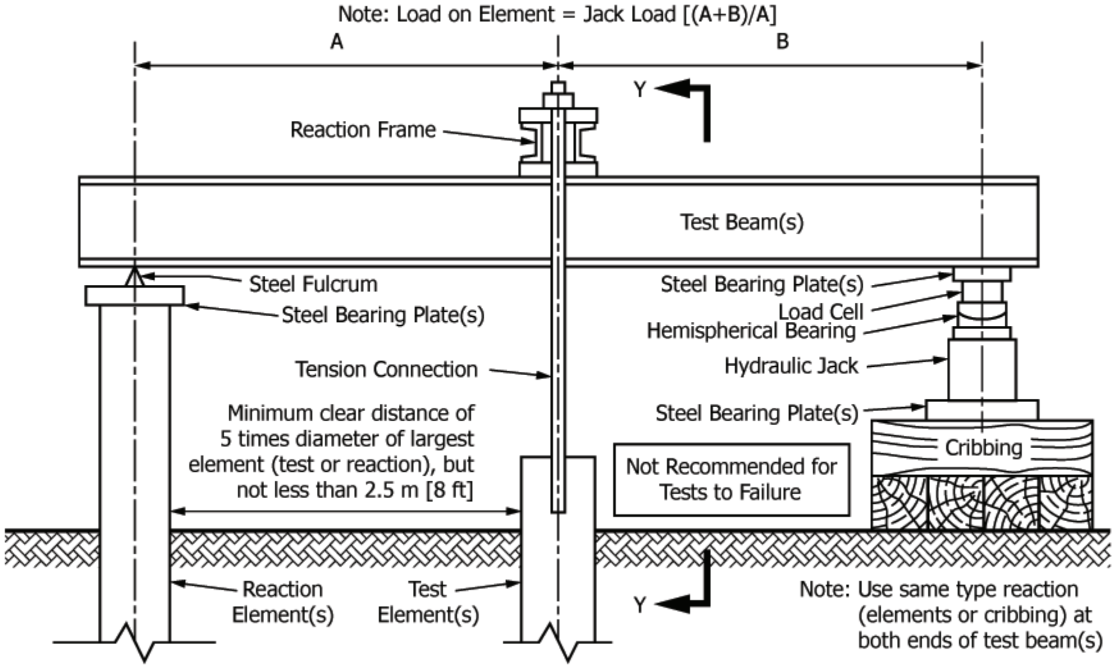

FIG. 6 Typical Setup for ~~Tensile~~ Load Test Using Hydraulic Jack(s) Acting Upward on One End of Test Beam(s)

load. Design and construct the test beam(s), reaction frame, and reaction ~~piles~~elements or cribbing, and arrange the jack(s) symmetrically ~~so as~~ to apply the resultant tensile load at, and parallel to, ~~to~~ the longitudinal axis of the test ~~pile or pile group.~~element.

8.6 *Load Applied ~~to Pile~~ by Hydraulic Jack(s) Acting at Top of an A-Frame or a Tripod* (Fig. 7) *(optional)*—Support an A frame

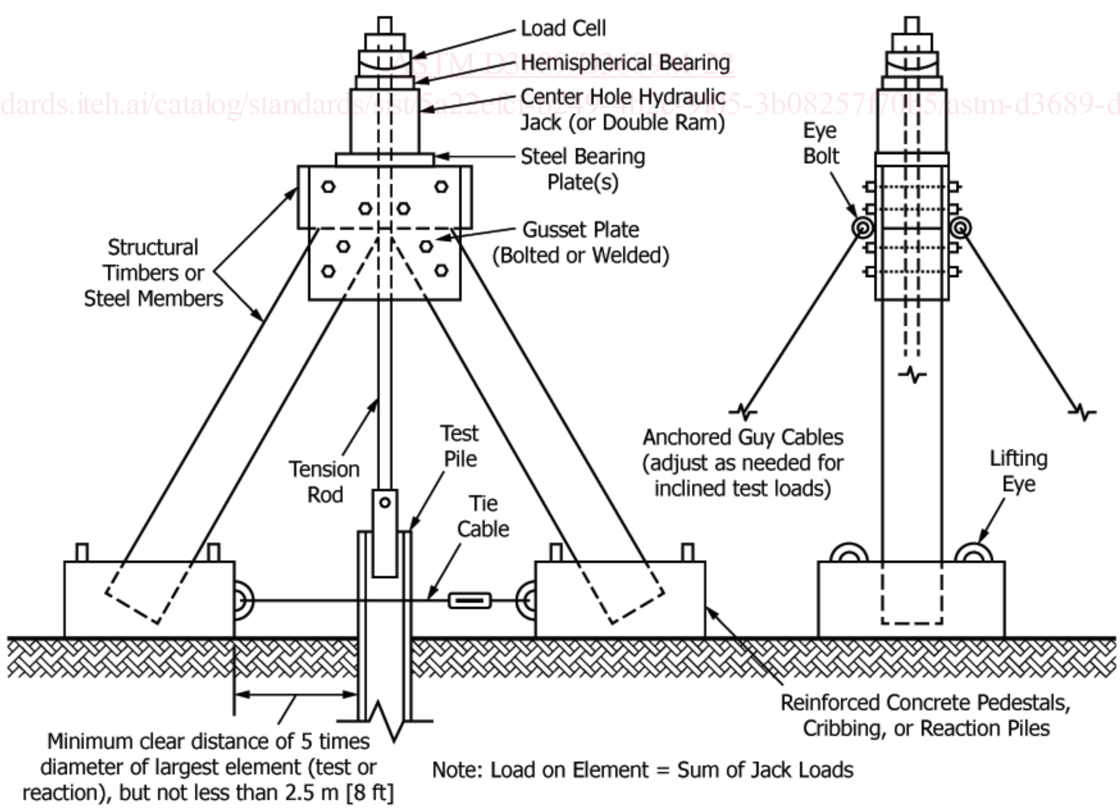

FIG. 7 Typical Setup for Tensile Load Test Using Hydraulic Jack(s) Acting at Top of an A-frame